

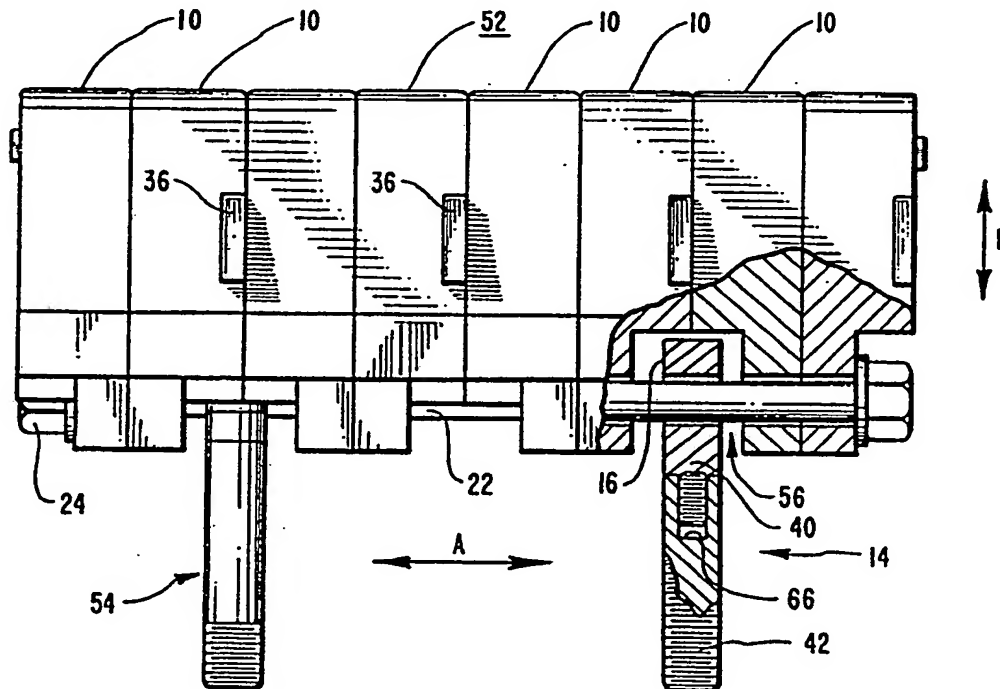
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<b>(21) International Application Number:</b> PCT/US90/00146 <b>(22) International Filing Date:</b> 3 January 1990 (03.01.90)  <b>(30) Priority data:</b> 295,740                      10 January 1989 (10.01.89)      US  <b>(71) Applicant:</b> AMERICAN MAGOTTEAUX CORPORATION [US/US]; 2409 21st Avenue South, Nashville, TN 37212 (US).  <b>(72) Inventors:</b> HARRIS, Terrance, R. ; Route 3, Box 322A, Pulaski, TN 38478 (US). LARSEN, Darrell, R. ; 1706 East 4620 South, Salt Lake City, UT 84117 (US).		<b>(74) Agents:</b> NYDEGGER, Rick, D. et al.; Workman, Nydegger & Jensen, 1000 Eagle Gate Tower, 60 East South Temple, Salt Lake City, UT 84111 (US).  <b>(81) Designated States:</b> AT (European patent), AU, BE (European patent), BR, CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), IT (European patent), LU (European patent), NL (European patent), NO, SE (European patent).  <b>Published</b> <i>With international search report.</i>

**(54) Title:** LAMINAR SEGMENT FOR USE WITH COMMINUTION EQUIPMENT

**(57) Abstract**

A novel laminar assembly (10) for use with comminution equipment, such as a liner for protecting the shell of an ore crushing mill or as a wear tip on a blow bar for use in a rock impact crusher. The laminar segment includes a plurality of laminae (10) which are attached to each other with a rod (22) extending through holes (18) positioned in the base of the laminae (10), thereby forming a segment of virtually any desired length. Mounting bolts (14) are configured in two pieces, with an axial hole (20) extending through the head of the mounting bolt (14) by which they are mounted to the rod (22) and thereby attached to the liner segment. A second piece (42) of the mounting bolt threadably engages the head of the bolt and extends through the mounting surface of the comminution equipment being used. The utilization of small laminae (10) enables the laminae (10) to be cast and heat treated such that the microstructure throughout the laminae (10) may be strictly controlled, thereby providing a laminae (10) with consistent hardness and toughness throughout the laminae (10).



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## LAMINAR SEGMENTS FOR USE WITH COMMINUTION EQUIPMENT

1

BACKGROUND1. Field of the Invention

The present invention relates to methods and apparatus  
5 for providing a protective lining and impacting surface for  
equipment used in ore and rock comminution. More  
particularly, the present invention relates to a new and  
improved liner assembly and mounting apparatus for  
providing the shell of an ore grinding mill with a liner  
10 having desired metallurgical properties.

2. The Background of the Invention

In commercial mining operations, large autogenous and  
semi-autogenous mills are often employed to comminute ore  
15 removed from the mine. Such mills include a large drum,  
having a typical diameter of 28 feet and a length of 12  
feet. In operation, ore is fed through a trunnion into the  
feed end of the drum while the drum is being rotated about  
a central axis. As the drum rotates, the ore is comminuted  
20 by being subjected to both continuous-pressure and impact  
mechanisms. The ore is then removed from the opposite, or  
discharge end of the mill.

These autogenous and semi-autogenous mills are  
typically intended for continuous operation. However,  
25 because ores being comminuted in the mill may be hard and  
highly abrasive, the drum will quickly wear out unless some  
provision is made to protect the drum from wear while the  
mill is in operation. Replacing the drum not only would  
cause a serious disruption in the operation of the mill,  
30 but would result in such a significant expense that the use  
of such a mill would be impractical.

The universally accepted solution for protecting the  
drum from wear is to employ a liner which may be mounted  
onto the cylindrical sections of the drum, or the "shell"  
35 of the mill. In recognition of this necessity to include  
a liner, when the drums are manufactured, a series of rows

1 of mounting holes are drilled into the shell of the mill.  
A series of liner segments may then be mounted onto the  
shell of the mill utilizing these mounting holes, thereby  
5 virtually completely covering the shell of the mill. These  
mounting holes are typically spaced in the axial direction  
(i.e., along the axis of rotation of the mill)  
approximately 12 to 24 inches apart.

After a period of use, the liner segments are worn to  
the point that they must be replaced. In order to reduce  
10 to a minimum the amount of down time of the mill associated  
with the replacement of liner, liner design has been  
directed towards facilitating rapid replacement of the  
liner.

It takes virtually the same amount of time to replace  
15 a large liner segment as it takes to replace a small liner  
segment. Thus, the trend in liner design has been to make  
liner segments as large as possible, resulting in fewer  
liner segments to replace. For example, by doubling the  
size of the liner segments, the number of liner segments  
20 which must be replaced is reduced by half. This results in  
a corresponding reduction in time required to replace the  
liner.

Because of the weight of the liner segments, special  
equipment is employed to lift the segments and place them  
25 in position for mounting to the shell of the mill. This  
"liner handler" is always used to support the liner  
segments during mounting. Thus, the increased weight  
associated with employing larger liner segments results in  
a negligible increase in the difficulty of replacing the  
30 liner.

In addition to being advantageous to mill operators in  
reducing the amount of down time of the mill during  
replacement, large liners also represent a significant  
economic advantage over smaller liners to liner  
35 manufacturers. A significant factor in determining the  
price which is charged for such liners is their weight.

1 Liners are usually priced by charging a predetermined  
amount per pound of material.

5 Because such liners are made by casting, a liner  
manufacturer may double the poundage of sellable material  
produced in one mold simply by doubling the size of the  
liner. It is not uncommon to produce a liner with one  
casting which results in several thousand pounds of  
material which is ready to sell. As is the case when  
10 installing the liner, casting a larger liner does not  
result in a marked increase in the amount of work involved.  
Thus, when producing liners having half the size, twice as  
much work is involved by the manufacturer to produce the  
same dollar volume of product.

15 Because of the enormous size and weight of most ore  
grinding mills, the size limit of steel plate which is  
available, the capacity of metal forming machines, and the  
transportation limitations which arise when dealing with  
such machinery, it is necessary to manufacture the mills in  
several sections which may be assembled at the mill site.  
20 The mills are typically made of cylindrical quadrants  
having flanges extending from their perimeter for mounting  
to one another. By representative example, when  
constructing the mill, the cylindrical quadrants are  
mounted lengthwise to each other to form a cylinder.  
25 Several cylinders may be mounted to each other to achieve  
the desired length of mill. End pieces may then be mounted  
to the ends of the cylinder to enclose the mill.

The joints along the circumference of the drum  
represent the weakest structural points in the drum. To  
30 compensate for this weakness, liners mounted inside the  
drum may be mounted such that they span these joints and  
are secured to the drum on both sides of the joints. Such  
a liner, therefore, serves a dual purpose; it provides a  
hard material used in comminuting the ore and it reinforces  
35 the structure of the drum, thereby lending stability to the  
mill.

1           From the foregoing, it can be seen that significant  
economic forces have dictated that the size of liners  
employed to protect the shell of the mill be as large as  
5   possible. Additionally, the use of large liners has been  
preferred because their size enables the liners to be used  
to reinforce the joints of the cylindrical quadrants which  
are mounted together to form the mill.

10          Replaceable impact surfaces found in other comminution  
equipment also tend to be large for many of the same  
reasons as described above. For example, the blow bar used  
in a rock impact crusher is preferably made of one piece,  
thereby keeping to a minimum the time involved to replace  
the blow bar. Additionally, manufacturing of the blow bar  
15   is facilitated if only one casting must be performed to  
produce the blow bar.

20          The use of large impact surfaces, however, does  
present various difficulties. For example, mill shell  
liners are preferably made of a material which is highly  
abrasion resistant in order to withstand virtually  
20   continuous contact with hard and highly abrasive ores.  
Additionally, the liner must be impact resistant so that it  
does not rapidly disintegrate due to brittle failure during  
operation of the mill.

25          Because the liner must have a high hardness, it is not  
feasible to machine the liner segments. Use of a material  
which would be machinable with conventional equipment would  
necessarily require use of a material which would not have  
sufficient hardness for use as a liner. Thus,  
30   manufacturing liner segments of a castable material is the  
only economically viable method of manufacture.

35          Although the properties of hardness and toughness are,  
to a large extent, exclusive of each other, a suitable  
combination of hardness and toughness may be obtained by  
heat treating the liner. An example of a material ideally  
suited for this application would be martensitic white iron  
or martensitic steel.

1 High hardness is obtained in the liner segment through  
heat treatment. After the liner segment has been cast, it  
is heated and allowed to "soak" at a given temperature for  
5 a period of time, thereby forming austenite. Following the  
austenite formation, the segment is rapidly cooled, or  
"quenched," to form martensite. The quenching must occur  
fast enough to avoid transformation to pearlite or bainite.

The primary difficulty which arises when attempting to  
quench a large casting to form a martensitic microstructure  
10 throughout the liner segment is that because of the  
thickness of the liner the rate of heat loss may not be  
sufficient to avoid transformation to another  
microstructure. This frequently results in the formation  
of a martensitic microstructure at the surface of the  
15 casting with other, softer microstructures being formed at  
the core. Additionally, the slower rate of solidification  
associated with the larger casting will produce a product  
having a larger grain size than a smaller casting, thereby  
adversely affecting the hardness of the final product.

20 One of the hazards of rapid quenching is the  
possibility of distorting and cracking the liner segment.  
As the surface portions of the liner segment pass through  
the martensite transformation, they will initially expand  
as the temperature in that portion of the liner drops and  
25 martensite is formed. The remainder of the liner is still  
austenite, soft and hot, and follows the expansion. Then,  
as the rest of the liner passes through the martensite  
transformation and the associated expansion, the surface  
portions of the liner, which are hard, brittle martensite,  
30 will frequently crack.

The manufacturing process must, therefore, be  
carefully monitored to ensure that the temperature gradient  
within the liner segments stays within acceptable limits,  
thereby avoiding cracking of the liner segments during  
35 quenching. Even though the liner segments may not crack,  
uneven quenching may set up residual stresses within the

1 liner segments which will decrease liner life. These  
difficulties associated with the production of liner  
segments having a martensitic microstructure obviously  
5 increase the cost of manufacture of such liner segments.

Thus, one of the primary disadvantages associated with  
the production of martensitic liner segments is that it is  
difficult to obtain the same degree of hardness in the core  
of the liner segment as at the surface. In operation, once  
10 the hard surface of the liner becomes worn, the remainder  
of the liner, which does not enjoy the same degree of  
hardness as the surface, will quickly wear. This obviously  
decreases the operational time of the mill between  
replacement of liners.

Another feature which adds to the difficulty of  
15 casting the liner segments is that bolt holes must be  
provided in the segments through which a bolt may be  
inserted to mount the liner segments to the mill shell.  
When preparing a mold which will cast a liner having a hole  
in it, an insert must be provided in the mold to form the  
20 hole. As the liquid metal is poured into the mold, it  
forms swirls and curls around the insert which results in  
a weak zone at that location. When the part fails, it  
usually fails at the hole.

In recognition of the weak zone which exists at the  
25 hole in the liner, most liners are designed such that the  
hole is not in the primary wear section of the liner. The  
liner is provided with a recessed area which includes the  
hole. The disadvantage with this configuration is that the  
wear section, or portion of the liner exposed to the ore  
30 stream, must necessarily be smaller to provide for the  
recessed portion containing the hole.

Attempts made to attach the mounting bolt to the liner  
thereby eliminating the through hole have failed because of  
problems associated with removing the liners. A typical  
35 liner segment may be mounted to the shell of the mill with  
several bolts. If an attempt is made to remove the liner



1 without first removing the bolts, the liner will bind  
because of the difficulty of evenly pulling the liner bolts  
out of the holes in the shell of the mill.

5 Thus, the usual practice for removing a liner segment  
is to first remove at least all but one of the bolts by  
removing the nut on the outside of the shell and pushing  
the bolt through the hole in the liner. The liner segment  
may then be broken loose and removed without any binding.

10 One proposed solution to the manufacturing problems  
encountered when attempting to produce a large liner  
segment having a hardness sufficient for use in a mill is  
to include one or more alloys in the casting. It is  
generally recognized that alloys may be used to produce a  
15 material having desired mechanical properties when the  
physical parameters of the casting prevent the material  
from being heat treated to attain those properties.  
Increasing the amount of alloys in the casting enables a  
liner having a coarser grain size to be produced with the  
same hardness as a non-alloyed material having a finer  
20 grain. Thus, alloys permit the successful hardening of  
many complex designs that could not otherwise be produced.

However, a serious disadvantage to the use of a  
substantial amount of alloys is their high cost. Although  
alloys may enable a desired hardness to be achieved in a  
25 complex design, the increased cost associated with the use  
of alloys may render the use of such alloyed liners  
impractical for many applications.

Another means employed by the prior art to achieve a  
liner assembly having a hard surface is to use a composite  
30 liner assembly. A composite liner is a liner assembly  
which employs a tough material for the primary structure of  
the liner coupled with one or more inserts or segments  
formed from a highly abrasion-resistant material which  
comprises a secondary structure. The tough primary  
35 structure is attached to the hard secondary structure in

1 such a manner that the hard inserts or segments are exposed  
directly to the ore fragments.

5 Composite liner assemblies are designed primarily for  
use in rod mills where there is no point contact. In ball  
mills and autogenous mills where there is a substantial  
amount of point contact with the liners, composite liners  
are not effective because the hard inserts only cover  
approximately 30 percent of the surface area of the shell  
of the mill.

10 Another disadvantage to such composite liner  
assemblies is that they are geometrically complex and  
utilize complicated mounting mechanisms. Thus, composite  
liner assemblies are frequently expensive to manufacture  
and, because of their many parts, are difficult to install.  
15 Additionally, when the hard secondary material eventually  
breaks away due to its brittleness, the hard inserts or  
segments must immediately be replaced before the primary  
structure is irreparably damaged by the abrasive action of  
the ore.

20 Because the primary structure serves no purpose other  
than as a mounting mechanism for the hard secondary  
structure, it adds weight to the already heavy mill without  
providing a corresponding increase in crushing efficiency.

25 It will be appreciated, therefore, that what is needed  
in the art are methods and apparatus for covering the shell  
of an ore grinding mill with a liner which may be easily  
and inexpensively installed and replaced.

30 It would be a further enhancement in the art if such  
liners could be manufactured such that the microstructure  
of the liner could be controlled during heat treatment,  
thereby producing a liner having the same microstructure  
throughout (such as a martensitic microstructure) and  
substantially the same grain size throughout.

35 Indeed, it would be yet a further advancement in the  
art if such a liner could be heat treated during the  
manufacturing process such that the risks of breaking the

1 liner and establishing significant residual stresses within  
the liner are substantially eliminated.

It would be an additional enhancement in the art if  
such liners could be provided with a mounting mechanism  
5 which eliminate the necessity for through holes in the  
liner, thereby avoiding weak zones in the wear section of  
the liner.

It would also be an advancement in the art if such a  
liner could be manufactured without employing significant  
10 amounts of expensive alloys.

It would be an additional advancement in the art if  
such liners could be manufactured without employing a  
composite liner assembly having a tough material as a  
primary structure and hard material for a secondary  
15 structure, thereby eliminating the complex, intricate  
configurations associated with such liner assemblies and  
providing a liner assembly having a lower weight than such  
composite liner assemblies.

Such methods and apparatus are disclosed and claimed  
20 herein.

#### BRIEF SUMMARY AND OBJECTS OF THE INVENTION

The present invention includes novel methods and  
apparatus for providing an impacting surface for use in  
25 comminution equipment such as a liner for the shell of an  
ore grinding mill. According to the present invention, a  
plurality of thin laminae are provided and configured such  
that they can be mounted together to form one substantially  
integral liner segment. The liner segment also employs  
30 novel liner bolts which mount the liner segment to the  
shell of the mill.

Each of the laminae is configured with a mounting  
channel in one side of the base of the lamina. When two  
laminae are placed together such that the mounting channels  
35 are in communication with each other, the mounting channels

1 combine to form a pocket into which the head of a liner  
bolt will fit.

Each of the laminae is configured with a hole which  
5 passes through the base of the laminae. The head of each  
liner bolt is also configured with a hole. The holes in  
the laminae and the head of the liner bolts are aligned  
such that when several laminae are placed together with  
liner bolts occasionally located in the pockets which are  
10 formed, a high-strength rod may be inserted through the  
laminae and the liner bolts. According to this unique  
mounting mechanism, no holes are necessary in the wear  
section of the laminae.

A nut may then be placed on the end of the rod and  
15 tightened to rigidly mount the laminae to each other. The  
rod also serves to attach the liner bolts to the laminae.  
The resulting liner segment may then be mounted to the  
shell of an ore grinding mill.

When tightening the nut on the bolt to rigidly mount  
together the laminae, it is preferred that the laminae all  
20 be aligned with each other. To assist in aligning the  
laminae during assembly, a recess and tab are cast into  
each lamina. The recess and tab are configured such that  
they form a mating connection when the laminae are stacked  
together. With the recess and tab of adjacent laminae in  
25 mating connection with each other, the laminae are  
substantially prevented from movement with respect to each  
other while the liner segments are being assembled.

The recess on one face of the lamina is in the same  
position as the tab on the opposite face of the same  
30 lamina. Additionally the laminae are configured such that  
each face is identical with respect to the positioning of  
the recess and the tab. This enables just one mold to be  
used in casting the laminae of the present invention. To  
preserve the ability to use one mold in manufacturing the  
35 laminae, it is preferred that the mounting channel be  
configured on the same side of each lamina.

1       The laminae may also be cast to include a chamber into  
which may be placed a lifting hook. When installing or  
removing the liners the lifting hook is engaged by the  
5       liner handler to grasp the liner segment. As with the  
mounting channel which accommodates the head of the liner  
bolt, the chamber for the lifting hook may be cast on the  
same side of each laminae thereby enabling only one mold to  
be used when forming the laminae.

10       The use of a plurality of small laminae to form an  
integral liner segment has tremendous metallurgical  
consequences. Because of the small size of the casting  
which produces the laminae, the temperature gradients  
within the laminae during heat treatment are substantially  
15       reduced. This enables the laminae to be heat treated to  
form virtually any type of microstructure which may be  
desirable for a given application.

      Because of the low temperature gradient upon cooling,  
the laminae will be formed with essentially the same micro-  
structure throughout; that is, the microstructure at the  
20       core of the laminae will be equivalent to that at the  
surface. The ability to exercise control over the  
microstructure of the laminae obviates the necessity of  
heavily alloying the laminae to compensate for the failure  
to obtain the desired abrasion-resistance and impact-  
25       resistant characteristics through heat treatment, such as  
frequently occurs in a conventional liner segment.

      The laminae may be rapidly quenched without the danger  
of cracking the laminae or forming residual stresses in the  
laminae. Additionally, because of the rapid cooling rate  
30       associated with the laminae, the laminae may be quenched  
with blast air, thereby avoiding the use of more expensive  
quenching mediums. A significant advantage to the use of  
the liner segments of the present invention is the fact  
that a martensitic microstructure, which only forms upon  
35       rapid quenching, may be formed throughout the laminae of  
the present invention by quenching with blast air.

1       The present invention also includes a novel liner bolt  
which, as intimated previously, eliminates the necessity of  
incorporating through holes in the wear sections of the  
liner segments. The liner bolt comprises two sections  
5       which threadably engage each other -- an interior and an  
exterior section.

      The interior section includes the head of the bolt and  
is mounted to the liner segment with the high-strength rod  
as described above. The exterior section of the liner bolt  
10       is configured to threadably engage the interior section of  
the liner bolt such that the resulting bolt has  
substantially the same length as a conventional liner bolt.  
The exterior section is also configured with threads such  
that when the bolt is inserted through a mounting hole in  
15       the shell of the mill, a nut may be threaded on the end of  
the bolt and tightened against the wall of the mill thereby  
placing the bolt in tension.

      When preparing to replace the liners in a mill, a  
sufficient number of liner segments must initially be  
20       assembled. The liner segments may be assembled to have  
virtually any length desired. As mentioned previously,  
there is a savings in labor when longer liner segments are  
used because the actual number of liner segments which must  
be mounted to the wall of the shell is reduced. Liner  
25       segments of five to six feet in length are not uncommon.

      Thus, in assembling the liner segments, laminae are  
"stacked" together with the recess and tab of abutting  
faces in mating connection. A number of liner bolts may  
then be inserted, where needed, in the pockets which are  
30       formed by the laminae. The rod is then placed through the  
hole running through the base of the laminae and the head  
of the liner bolts and a nut threaded on the end of the  
rod.

      Before tightening the nut on the rod, a number of  
35       lifting hooks may be placed in the liner segment by  
inserting them in the chamber which has been cast in the

1 laminae. By tightening the nut, the laminae are rigidly  
mounted to each other and a substantially integral liner  
segment is formed. The liner bolts and the lifting hooks  
5 also become connected to the liner segment upon tightening  
of the nut.

To obtain a sufficiently tight mount, it may be  
desirable to heat the rod before inserting it through the  
laminae and tightening the nut on the end. By manually  
10 tightening the nut on the rod while the rod is hot, it is  
possible to take advantage of thermal expansion and  
contraction to achieve a tighter mount. As the rod cools,  
it will contract to its original size thereby applying an  
even greater compressive force to hold the laminae  
together.

15 The spacing of the mounting holes in the shell of the  
mill may vary from mill to mill. Thus, when assembling the  
liner segments, it is only necessary to place a liner bolt  
in those pockets in the liner segments which correspond in  
position to the mounting holes in the shell of the mill.  
20 It may be preferable not to include a liner bolt for every  
mounting hole, depending on how firmly the liner must be  
mounted to the shell of the mill.

When mounting liner segments made according to prior  
art designs, the liner is brought into the mill with the  
25 liner handler and held against the shell of the mill for  
mounting. These prior art liner segments are configured  
with holes extending completely through the liner segment  
through which a liner bolt may be inserted. Thus, when the  
liner is placed against the shell, a worker may insert a  
30 liner bolt through the hole in the shell and the hole in  
the liner.

As mentioned previously, the existence of "through  
holes" in the liner is disadvantageous because it weakens  
the liner and usually results in a more complex liner  
35 casting because of efforts to keep the through holes away  
from the primary wear surfaces of the liner. Additionally,

1 eliminating through holes in the liner gives rise to  
problems when mounting the liner.

5 For example, rigidly mounting the liner bolt to the  
liner segment, thereby eliminating the through hole in the  
liner segment, has been one proposed solution. However, in  
order to mount such a liner segment to the shell of the  
mill, all the liner bolts must simultaneously be inserted  
through the mounting holes in the shell of the mill.  
10 Because this is accomplished from the inside of the mill,  
it is difficult to see the mounting holes because the view  
of the holes is obstructed by the liner segment. By  
employing the novel mounting assembly of the present  
invention, the problems associated with these "blind" holes  
may be remedied.

15 According to one embodiment of the present invention,  
a conventional liner bolt (as modified with a hole in the  
head of the bolt) is employed in each liner segment, as  
will be explained below in greater detail. Thus, all other  
liner bolts attached to the segment are two-piece liner  
20 bolts, configured according to the present invention.

The interior section of the two-piece liner bolts  
includes a threaded male member. The exterior section is  
configured with a corresponding threaded female member.  
The outside of the exterior section is also threaded,  
25 thereby enabling a bolt to be screwed onto the exterior  
section and cinched against the shell of the mill.

When installing a liner segment, the segment is  
brought through the trunnion of the mill with the  
assistance of the liner handler. The segment is then  
30 placed in alignment with the mounting holes in the shell of  
the mill and the single conventional liner bolt is inserted  
through the mounting hole in the shell of the mill, thereby  
refining the alignment of the liner segment with respect to  
the mounting holes.

35 Workers located on the outside of the mill may then  
insert exterior sections of liner bolts through the



1 mounting holes in the shell and thread them onto the  
corresponding interior sections. After the exterior  
sections of liner bolts have all been fully threaded onto  
5 the inside sections, a washer and nut may be placed on the  
exterior sections and tightened. As the nut is tightened,  
it draws the liner bolt out of the hole such that the liner  
segment becomes rigidly seated against the inside of the  
mill.

10 In an alternative embodiment of the present invention,  
the liner bolt may include a stud segment which is included  
in the pocket between adjacent laminae. The stud segment  
is provided with a hole which aligns with the hole in the  
laminae through which the rod is inserted to attach the  
15 laminae together. Also, the stud segment is threaded at  
its base. Thus, when mounting the liner segments, a  
threaded rod may be inserted from the outside of the mill  
through the hole in the shell of the mill and threaded  
directly into the stud segment.

20 On some mills, a liner plate is employed between the  
liner segment and the shell of the mill. The liner plate  
is typically made of a material which has high impact  
resistance. Thus, the liner plate protects the shell while  
the liner segments provide a hard surface against which the  
ore may be comminuted.

25 The liner plate may employ a variety of configurations  
which are conventional in the art. However, regardless of  
the geometry of the liner plate, the base of the liner  
segment may be configured such that when it is mounted to  
the shell of the mill it seats firmly against the liner  
30 plate.

When the liner segments become worn and need  
replacement, the first step in the removal process is to  
break loose the nuts on the exterior section of the liner  
bolts. When attempting to break the nuts loose, it is not  
35 uncommon for the exterior section of the liner bolt to  
break loose from the interior section. To the extent this

1 occurs, the removal process is facilitated because after  
the nuts have been removed from the exterior sections of  
the liner bolts, the exterior sections must be broken loose  
from the interior sections and removed.

5 When the exterior sections of the two-piece liner  
bolts have all been removed, only the one-piece,  
conventional liner bolt will remain protruding through the  
shell of the mill. The liner may then be broken away from  
10 the shell and/or the liner plate by applying an impact  
force on the remaining liner bolt from the outside of the  
mill. The worn liner segment may then be removed from the  
mill and a new liner segment put in its place.

It is, therefore, a primary object of the present  
invention to provide methods and apparatus for protecting  
15 the shell of an ore grinding mill with a liner assembly  
which may be easily and inexpensively installed and  
replaced.

It is also an object of the present invention to  
provide such methods and apparatus such that the  
20 microstructure of the liner assembly may be controlled  
during manufacture while substantially eliminating the  
danger that the liner will crack or develop internal  
stresses during quenching.

It is a further object of the present invention to  
25 provide such methods and apparatus such that through holes  
may be eliminated from the wear section of the liner  
assembly while allowing the liner to be removed from the  
mill without binding.

It is an additional object of the present invention to  
30 provide such methods and apparatus which employ a segmented  
liner having sufficient metallurgical properties such that  
the use of expensive alloys may be substantially avoided.

Other objects and advantages of the present invention  
will become apparent upon reading the following detailed  
35 description and appended claims, and upon reference to the  
accompanying drawings.

1

### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an exploded perspective view of one lamina and one two-piece mounting bolt according to the present invention.

Figure 2 is a side view of a liner segment illustrated with one conventional liner bolt and one two-piece liner bolt, with portions of the laminae broken away to more clearly illustrate the relationship between the laminae and the liner bolts.

Figure 3 is a cross-sectional view of a liner segment mounted to the shell of an ore grinding mill.

Figure 4 is a partially exploded perspective view of an alternative embodiment of the two-piece mounting bolt according to the present invention, with portions of the stud anchor broken away to more particularly illustrate the configuration of the holes in the stud anchor.

Figure 5 is an exploded perspective view of a two-tiered liner segment according to the present invention.

Figure 6 is a partially exploded perspective view of the present invention as used on the blow bar of a rock impact crusher, with portions broken away to more particularly illustrate how the wear tip is mounted to the carrier bar.

25

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Reference is now made to the drawings wherein like parts are designated with like numerals throughout. The present invention is directed to methods and apparatus for lining the shell of an ore grinding mill. Referring now to Figure 1, a lamina according to the present invention is designated at 10. Lamina 10 includes a mounting channel 12 which is configured to receive a liner bolt 14.

Liner bolt 14 includes a polygonal head 16. Thus, mounting channel 12 is configured such that approximately half of head 16 of liner bolt 14 fits within mounting

1 channel 12. Mounting channel 12 is further configured with  
a hole 18 and as head 16 of the liner bolt is configured  
with a corresponding hole 20. Thus, when head 16 of the  
5 liner bolt is received in mounting channel 12, hole 18 and  
hole 20 are aligned. Although liner bolt 14 is illustrated  
with a polygonal head 16, it will be appreciated that liner  
bolts having heads of a variety of geometries may be  
employed according to the present invention. However, it  
10 is more difficult to drill a hole through the head of the  
bolt if there is not a flat surface against which to start  
drilling the hole.

When forming a liner segment according to the present  
invention, a plurality of laminae 10 are placed adjacent  
each other and a rod 22 is placed through the extended hole  
15 formed when each hole 18 and hole 20 are aligned. A rod  
nut 24 may then be threaded on the end of rod 22 to fasten  
the plurality of laminae together, as is explained in  
further detail below. Rod 22 is preferably made of a high-  
strength alloy steel. It is important that the rod be  
20 strong because if the rod fails, the laminae will become  
disassembled.

Lamina 10 includes a face 26 on which is configured a  
tab 28 and a recess 30. The opposite side of face 26 (not  
shown) includes a tab corresponding in position to recess  
25 30 and a recess corresponding in position to tab 28. Thus,  
when a plurality of laminae are placed in alignment with  
one another by placing the faces of the laminae together,  
the tab on one lamina will engage the recess on the  
adjacent lamina in mating connection. Because each  
30 connection includes two tab/recess connections, the laminae  
are prevented from movement relative to each other because  
of the mating connection of the tabs and recesses.

Lamina 10 is further configured with a chamber 32  
which includes two keyed sections 34. Chamber 32 is  
35 designed such that a lifting hook 36 may be placed in  
chamber 32 when a liner section according to the present

1 invention is assembled. Thus, lifting hook 36 includes two  
keyways 38 which engage keyed sections 34 when lifting hook  
36 is placed in chamber 32.

5 In a presently preferred embodiment of the invention,  
chamber 32 is cast in only one face of each lamina. Thus,  
when two laminae are placed together in mating connection,  
there is not a corresponding chamber in the face of the  
adjacent lamina which aligns with chamber 32. Accordingly,  
10 chamber 32 is cast to have the same thickness as lifting  
hook 36.

It can be observed by reference to Figure 1 that only  
one mold is necessary for casting the laminae employed by  
the present invention. Thus, when assembling a liner  
segment, a lamina identical to lamina 10 will be aligned  
15 with liner 10 such that the mounting channels are in  
communication with each other. Face 26 must therefore be  
configured such that tab 28 and recess 30 are in  
symmetrical positions with respect to each other.

With continued reference to Figure 1, liner bolt 14  
20 includes an interior section 40 and an exterior section 42.  
Interior section 40 includes a threaded male member 44 at  
its base. Threaded male member 44 corresponds to a  
threaded female member 46 configured in exterior section  
42. Thus, male member 44 and female member 46 are  
25 configured such that they may threadably engage each other.  
As will be pointed out in greater detail below, the use of  
a two-piece liner bolt, as illustrated in Figure 1, greatly  
facilitates installation and removal of the liner segments.

A washer 48 and a mounting nut 50 are also provided  
30 for use on exterior section 42 of liner bolt 14. When used  
to mount a liner segment to the shell of a mill, washer 48  
and mounting nut 50 are placed on liner bolt 14 from the  
outside of the mill and tightened against the shell of the  
mill to provide a firm mount of the liner segment.

35 Referring now to Figure 2, a liner segment according  
to the present invention is illustrated. In Figure 2, a

1 plurality of laminae 10 are illustrated in interconnection  
to form a liner segment 52. Liner segment 52 is  
illustrated with two liner bolts -- a two-piece liner bolt  
14 and a conventional liner bolt 54.

5 When mounted in an ore grinding mill, the liner  
segments are mounted on the shell of the mill in the  
"axial" direction -- parallel to the axis of rotation of  
the mill. Thus, as used herein, the "axial" direction  
refers to the direction parallel to the axis of rotation of  
10 the mill, or along the direction of arrow A in Figure 2.

It will be appreciated by one skilled in the art that  
the apparatus and methods of the present invention may also  
be used to provide liners configured for mounting along the  
walls of the feed cone and the discharge cone, as well as  
15 other areas in the mill in which liners are employed.  
Although such liners are not always mounted parallel to the  
axis of rotation of the mill, "axial direction," as used  
herein, shall refer to the direction of the length of the  
liner segments, as indicated by arrow A.

20 When mounted on the shell of the mill, the liner bolts  
are directed in the "radial" direction -- the direction  
extending outwardly from the axis of rotation of the mill  
in a plane perpendicular to that axis. Accordingly, the  
"radial direction," as used herein, refers to that  
25 dimension of the liner segment indicated by arrow B in  
Figure 2.

Finally, as used herein, the "transverse" direction  
refers to the direction parallel to a line tangent to the  
shell of the mill at a right angle to the axis of rotation  
30 of the mill. The "transverse" direction, as used to refer  
to a dimension of a liner segment, is indicated in Figure  
3 by arrow C.

As can be noted by reference to Figures 1 and 2, liner  
segment 52 comprises a plurality of laminae whose smallest  
35 dimension is in the axial direction. Whereas the prior art  
liners usually have their largest dimension in the axial

1 dimension. As noted above, prior art liners with lengths  
of five and six feet are not uncommon.

5 When manufacturing liners for use in an ore grinding  
mill, it is desirable to cast and heat treat the liners  
such that substantially the same microstructure is  
developed throughout the liner. That is, the  
microstructure in the core of the liner is the same  
microstructure as on the surface of the liner. As used  
10 herein, "heat treating" also encompasses conventionally  
known methods of forging.

However, some microstructures are particularly  
difficult to obtain when high temperature gradients exist  
in a material upon quenching. If the core temperature of  
a material cannot be reduced at a sufficiently fast rate,  
15 the desired microstructure will not be developed.

For example, when manufacturing liners for use on the  
shell of an autogenous mill, it is preferred that the liner  
have an optimum combination of abrasion resistance and  
impact resistance. Thus, a liner which is both tough and  
20 hard is ideal for use in such an application.

It has been found that an acceptable combination of  
hardness and toughness can be achieved by employing a liner  
having a martensitic microstructure. A martensitic  
microstructure, however, can only be achieved upon rapid  
25 quenching. Indeed, the hardenability of the liner segment  
may be limited by the cooling rate which may be realized in  
the segment. Thus, many liners cannot be made with a  
martensitic microstructure throughout the liner because  
they are so large that rapid quenching, particularly at the  
30 core of the liner segment, may not be obtained.

If the desired microstructure cannot be achieved  
through heat treating, resort must be made to the addition  
of extra alloys to increase hardenability and thereby  
provide the liner with sufficient hardness and toughness.  
35 Alloys, of course, may add significantly to the cost of the  
liner. Thus, if a high cooling rate may be obtained,

1 hardenability is increased while maintaining a low level of  
alloying elements.

5 The ability to quench rapidly is therefore the key to  
maintaining control over the microstructure of the liner.  
Frequently the physical limitations on a particular product  
prevent that product from successfully being subject to  
rapid quenching. Whether a particular product can be  
10 rapidly quenched can be visualized as a function of how far  
the heat must travel from the core of the product to the  
surface. Thus, the greater the minimum distance from the  
innermost core of the product to the surface, the higher  
the temperature gradient during quenching will be for a  
given cooling medium.

15 Without changing the material out of which the product  
is made, the temperature gradient may be decreased by  
simply altering the configuration of the product such that  
the distance from the core of the product to the surface is  
reduced. With respect to mill liners, it has heretofore  
20 been perceived as impossible to substantially alter the  
distance from the core of the liner to the surface.

As mentioned previously, substantial economic forces  
have dictated that the length (axial direction) of liners  
be maximized. The height (radial direction) and width  
(transverse direction) of liners has also needed to be  
25 maximized to provide a sufficient wear section in the  
liner, thereby maximizing the life of the liner and  
resulting in a corresponding reduction in down time of the  
mill.

30 The "wear section" of the liner is that portion of the  
liner which is directly exposed to impact forces from the  
ore or other media in the mill to assist in the comminution  
of the ore. After the wear section of the liner has been  
worn out, the liner must be replaced. Thus, when designing  
liners, primary importance must be given to the  
35 metallurgical properties of the wear section of the liner.



1 By incorporating a laminar design, the present  
invention provides a lamina which may be assembled with  
other laminae to present virtually any axial length of  
liner segment. Thus, virtually any cross-sectional shape  
5 (perpendicular to the axial direction as viewed in Figure  
3) may be employed while maintaining the ability to control  
the microstructure of the laminae during casting and heat  
treating. This control may be maintained because the rate  
of quenching is no longer tied to those cross-sectional  
10 dimensions (transverse and radial).

The laminae of the present invention may therefore be  
manufactured having a selected microstructure throughout  
the laminae, which microstructure could not be otherwise  
achievable in unitary large castings. Preferred materials  
15 for use in manufacturing the laminae of the present  
invention include both irons (carbon content greater than  
approximately 1.25 percent) and steels (carbon content  
between approximately 0.3 and 0.7 percent). More  
particularly, high-chromium white irons having a carbon  
20 content from approximately 2.5 to approximately 3.0 percent  
also provide an ideal material from which to manufacture  
laminae according to the present invention.

Of course, it is impossible to obtain the exact same  
metallurgical properties at the core of a product as at the  
25 surface. To do so would require that there be absolutely  
no temperature gradient in the material upon quenching;  
which is impossible. However, for commercial purposes, the  
temperature gradient in the laminae of the present  
invention does approach uniformity sufficiently to make the  
30 microstructure of the laminar essentially uniform.

Thus, as used herein, when a part is said to have  
"substantially the same metallurgical microstructure  
throughout," it is meant to comprise a generally equivalent  
grain size and/or microstructure character; when  
35 considering the application for which the liners of the  
present invention are intended; recognizing that quality

1 control and natural properties and impurities of materials  
will result in some deviation between core and surface.  
The same is true as applied to "grain size" or other  
5 properties, such as hardness and toughness.

5 The microstructure is made essentially equivalent by  
sizing the axial length of each lamina such that the  
temperature gradient is more uniform during cooling. The  
center of the core is that interior location of the lamina  
10 which is farthest from all cooling surfaces. In Figure 3,  
the center of the core is approximately midway along the  
axial length and essentially equidistant between the top of  
lamina 10 and the top of mounting channel 12. In selecting  
conditions conducive to microstructures which are  
15 equivalent throughout the liner, an axial dimension which  
is small compared to the transverse and radial dimensions  
is most advantageous. Thus, the center of the core is  
closer to the faces 26 during cooling than it is to other  
surfaces.

20 Generally speaking, the closer the center of the core  
is to a surface, the more favorable the conditions are for  
achieving a microstructure which is equivalent throughout  
the liner. In the present invention, the distance from the  
center of the core along the axial length of each lamina  
should be less than the distance from the center of the  
25 core to the surface in the radial or transverse direction.

After the laminae according to the present invention  
have been formed with the desired properties, they are  
combined to form a liner segment which may be configured  
with liner bolts and mounted to the shell of the mill.

30 The spacing between liner bolts is primarily a  
function of the mounting hole pattern in the mill in which  
the liner segment is being installed. Typical spacing of  
mounting holes in the shell of the mill ranges from 12 to  
24 inches. When the liner segment is assembled, the liner  
35 bolts may be placed in the liner segment such that they  
correspond to the hole pattern in the mill. Thus, the

1 liner segments of the present invention may easily be  
configured to fit virtually all conventional grinding  
mills.

5 When assembling liner segment 52, a sufficient number  
of laminae 10 are "stacked" together to form the length of  
liner segment which is desired. In one representative  
example, each lamina of Figure 2 is approximately three  
inches in length. Significantly, the length is less than  
10 the radial or transverse dimensions. Thus, to form a 24  
inch liner segment, eight laminae must be used. It will be  
appreciated that liner segments may be assembled having any  
length which is conventionally known for use in such ore  
grinding mills. The ability to assemble a variety of  
15 lengths of liners represents a significant advantage to  
liner manufacturers because it eliminates the need to  
maintain an inventory of each length of liner which might  
be requested.

When stacking the laminae together, they are placed  
such that the face of one lamina engages the identical face  
20 of each adjacent lamina. With the laminae so placed, the  
tab and recesses on adjacent laminae engage each other in  
mating connection, thereby preventing relative movement of  
the laminae. Also, mounting channels 12 of the lamina are  
in communication with each other thereby forming a pocket  
25 56. The liner bolts may be attached to the liner segment  
by inserting the head of the liner bolt in the pocket 56  
corresponding to the location along the liner segment where  
a liner bolt is desired.

With the laminae in stacked relation to each other  
30 such that the tab and recesses are in mating connection and  
liner bolts inserted in the desired pockets 56, rod 22 may  
be inserted through hole 18 in the base of each lamina and  
through hole 20 in the head of each liner bolt. By  
threading nut 24 on the end of rod 22, the liner segment  
35 may be rigidly secured to form an integral liner segment.

1 When assembling long liner segments, it may be  
difficult to tighten nut 24 on rod 22 as much as desired.  
Thus, when assembling long liner segments, it is preferred  
5 to heat rod 22 such that its length will increase due to  
thermal expansion. In the expanded state, rod 22 may be  
placed through the laminae and nut 24 tightened as much as  
possible. As rod 22 cools, it will attempt to contract to  
its original length thereby imparting a significant  
compressive force on the lamina to secure them together.

10 By reference to Figure 3, the mounting mechanism  
according to the present invention is illustrated and may  
be explained. In Figure 3, a liner segment of the present  
invention is shown in cross section, as mounted to a shell  
58. Shell 58 is illustrated with a liner plate 60  
15 providing a seat 62 into which the liner segment is  
mounted.

When installing liner segment 52, a liner handler is  
used to grasp liner segment 52 by lifting hook 36 and hold  
it up to the shell of the mill in the approximate location  
20 where it is desired to mount the liner segment. At this  
point, conventional liner bolt 54 (Figure 2), which is  
preferably included in each liner segment, may then be  
inserted through the hole in the shell of the mill which  
corresponds to liner bolt 54.

25 Workers located on the outside of the mill may then  
insert exterior section 42 of liner bolt 14 through  
mounting hole 64 in the shell of the mill. After exterior  
section 42 has been inserted through the shell of the mill,  
threaded female member 46 of exterior section 42 may be  
30 threaded onto threaded male member 44 of interior section  
40 of liner bolt 14. Thus, the workers on the outside of  
the mill can locate each liner bolt individually and  
connect the exterior and interior section of the liner bolt  
together.

35 By eliminating through holes in the liner, it is no  
longer possible to simply line up the holes and insert a

1 bolt through the liner and the shell of the mill, such as  
is typically done when mounting liners having through  
holes. Without the two-piece liner bolts of the present  
invention, conventional liner bolts would have to be  
5 attached to the liner segments.

Thus, workers on the inside of the mill would be faced  
with the challenge of simultaneously aligning all of the  
liner bolts with their corresponding holes and holding that  
alignment while the liner is pushed against the shell,  
10 thereby inserting all the liner bolts through the holes for  
mounting. The problem of aligning the liner bolts with the  
mounting holes in the shell of the mill is further  
exacerbated by the fact the presence of the liner obstructs  
the view of the holes. These mounting problems which have  
15 previously prevented the elimination of through holes in  
the liner, are avoided by employing the mounting mechanism  
of the present invention.

Following the connection of exterior section 42 to  
interior section 40 to form an integral liner bolt, washer  
20 48 and mounting nut 50 may be inserted on the end of  
exterior section 42 of the liner bolt. As mounting nut 50  
is tightened, it pulls the entire liner bolt toward the  
exterior of the mill, in the direction of arrow D. The  
liner bolt acts on rod 22 which transfers this force in the  
25 direction of arrow D to the liner segment. Thus, as  
mounting nut 50 is tightened on liner bolt 14, each lamina  
10 is seated against seat 62.

The shape of the base of lamina 10 is preferably  
configured to match the geometry of liner plate 60. It  
30 will be appreciated by one skilled in the art that a  
variety of liner plates may be employed in combination with  
the present invention. For example, some liner plates may  
permit the base of the lamina to rest against the inside  
wall of shell 58, with a portion of the lamina resting  
35 against a seat, similar in configuration to seat 62.

1 Although exterior section 42 of the liner bolt is  
illustrated as including female member 46 and interior  
section 40 of the liner bolt is illustrated as including  
male member 44, it will be appreciated that these  
5 configurations may be reversed. Thus, the advantages of  
the present invention are also realized with interior  
section 40 configured to include the threaded female member  
and exterior section 42 configured to include the threaded  
male member.

10 Additionally, exterior section 42 may also be  
configured as a cap screw without departing from the  
present invention. If a cap screw configuration is  
employed, care must be taken to ensure that the threaded  
female member is sufficiently long that the cap screw does  
15 not bottom out when tightened. If a cap screw is employed  
rather than the threaded rod/nut combination illustrated in  
Figure 3, the liner segment is tightened against the mill  
shell by tightening the connection comprising the male and  
female members. This is in contrast to the configuration  
20 illustrated in Figure 3 in which the mounting nut 50 is  
tightened to seat the liner segment against the shell only  
after the two pieces of the liner bolt have been secured to  
each other.

25 While such variations of the mounting mechanism, as  
discussed above, are contemplated as being within the scope  
of the present invention, it is presently preferred that  
the mounting mechanism be configured substantially as  
illustrated in Figure 3.

30 With continued reference to Figure 3, it will be  
observed that the bottom 66 of threaded female member 46 of  
liner bolt 14 does extend inwardly beyond the exterior  
surface of shell 58. Because liner bolt 14 is subjected to  
significant lateral forces resulting in shear stresses on  
liner bolt 14, it is preferred that the cross section of  
35 exterior section 42 of the liner bolt not include the  
threaded female member at the exterior wall of shell 58.

1 By having a solid cross section at that point, the liner  
bolt is better able to withstand the forces applied to it  
while the mill is in operation. Thus, bottom 66 is  
5 preferably a distance E from the outside surface of the  
liner shell. In a preferred embodiment, distance E is  
approximately 1/4 inch.

Several provisions are made by the present invention  
to account for the lack of precision in the tolerances of  
mounting holes in the mill shell. For example, as can be  
10 best viewed in Figure 2, the liner bolts attached to liner  
segment 52 with rod 22 are capable of slight movement in  
the axial direction, i.e., along the line of arrow A.  
Thus, when installing the liner segment, if the mounting  
holes in the mill shell are not spaced within tight  
15 tolerances, the liner segment of the present invention is  
not precluded from being mounted to the shell.

As illustrated in Figure 3, there is also a degree of  
movement between head 16 of the liner bolt and mounting  
channel 12 in the base of the laminae. This enables liner  
20 bolt 14 to have a sufficient degree of freedom that it may  
be directed into the mounting hole in the mill shell even  
though the spacing of those holes may not be within the  
tolerances anticipated by the liner manufacturer.

When the liners become worn, removal of the liners may  
25 be easily and quickly accomplished. With continued  
reference to Figure 3, when it is necessary to remove the  
liners, mounting nut 50 may be broken loose and removed  
from each liner bolt 14. After each mounting nut 50 has  
been removed, each exterior section 42 may then be  
30 unscrewed from interior section 40 of the liner bolts.  
Advantageously, when employing a two-piece liner bolt,  
occasionally while attempting to break loose mounting nut  
50, the threaded connection between interior section 40 and  
exterior section 42 of the liner bolt will come loose  
35 first.

1 With all of the mounting nuts and the exterior  
sections of the liner bolts removed, the liner section may  
then be broken loose by applying an impact force to  
conventional liner bolt 54. The worn liner segment may  
5 then be removed through the trunnion of the mill with the  
assistance of the liner handler. A new liner is then  
brought into the mill and mounted in its place, following  
the procedure substantially as described above.

10 An alternative embodiment of the liner bolt according  
to the present invention is illustrated in Figure 4. A  
lamina 68 is configured with a mounting channel 70  
substantially as previously described. A stud anchor 72 is  
employed within mounting channel 70 in the same manner as  
the head 16 of liner bolt 14 in Figure 1 fits within  
15 mounting channel 12.

Each stud anchor 72 is configured with an axial hole  
74 extending completely through the anchor in the axial  
direction. Additionally, each stud anchor includes a  
radial hole 76 extending upwardly from the bottom of each  
20 anchor. In a presently preferred embodiment of the  
invention, radial hole 76 extends upwardly a sufficient  
distance such that it is in open connection with axial hole  
74, as illustrated in Figure 4.

When employing stud anchors 72 to mount liner segments  
25 according to the present invention, a plurality of lamina  
are stacked together and aligned by means of tabs 77 and  
recesses 78. A stud anchor 72 is inserted in pocket 79  
formed by the mating mounting channels 70 of the laminae.

Because it is only necessary to employ a stud anchor  
30 where a liner bolt will be used to mount the liner segment  
to the shell of the mill, laminae may be configured without  
mounting channel 70 where no stud anchor is used. Thus,  
"internal" laminae 80, configured without a mounting  
channel, may be employed in combination with "end-and-stud"  
35 laminae 82, configured with a mounting channel, to form the  
liner segment.



1        It will be noted that internal laminae 80 are also  
configured with an axial hole 84 in the base of each lamina  
through which a rod 86 may be inserted. Thus, in  
5 assembling the liner segment as illustrated in Figure 4, a  
plurality of laminae are stacked together with end-and-stud  
laminae 82 employed where a liner bolt will be attached to  
the laminae and on the ends of the liner segment. Internal  
laminae are preferably used in all other locations and  
10 essentially act as fillers between the end-and-stud  
laminae.

When mounting a liner segment configured as shown in  
Figure 4 to the mill shell, the liner segment is brought  
through the trunnion of the mill and held against the shell  
of the mill. Workers on the outside of the mill may then  
15 insert a threaded rod 87 through the mounting holes in the  
mill shell and thread the rod into axial hole 76 in stud  
anchor 72. A washer and nut may then be placed on the  
threaded rod on the outside of the mill shell and  
tightened, thereby securing the liner segment in place.

20        When removing the liner segment after it is worn, the  
nuts on the exterior of the mill shell are loosened from  
their corresponding threaded rods. The rods may then be  
unscrewed from the stud anchor and the liner segment broken  
loose and removed from the mill. It may be desirable to  
25 remove all but one rod from each liner segment and then  
apply an impact force to the remaining rod from the  
exterior of the mill to assist in breaking the liner  
segment loose.

It has been found that grinding efficiency is improved  
30 if an uneven surface is provided within the mill. To take  
advantage of this potential for increased efficiency, a  
mill may be lined with rows of liner segments which  
alternate in height. For example, one row of liners may be  
approximately 9 inches high (in the radial direction) with  
35 alternating rows being approximately 18 inches high.

1       Some equipment used in producing laminae according to  
the present invention have size limitations which would  
prevent an 18 inch laminae from being produced in one  
piece. Thus, the present invention may be utilized to  
5       employ a two-tiered liner segment.

      In Figure 5, such a two-tiered liner segment is  
illustrated. The two-tiered liner segment includes two  
end-and-stud laminae 88 corresponding to each liner bolt  
and one end-and-stud lamina at each end of the segment. A  
10       stud anchor 92 fits within the mounting channels 93 of two  
end-and-stud laminae which are stacked together such that  
their respective mounting channels are in mating  
connection, thereby enabling the liner segment to be  
mounted to the mill shell as described in connection with  
15       Figure 4. When the laminae are stacked together, they are  
properly aligned by means of tab 94 and recess 95  
configured on each laminae. Again, internal laminae 90 are  
preferably used as fillers between the end-and-stud  
laminae.

20       A top element 96 is provided for each laminae. Each  
top laminae 96 is configured with a tab 97 and recess 98 to  
aid in aligning the top elements during assembly of the  
liner segment. A mounting channel 99 and an axial hole 100  
which are used in combination with a rod 102 to mount the  
25       top laminae to the internal and end-and-stud laminae. As  
can be seen by reference to Figure 5, each internal laminae  
90 also includes a top hole 106 and a top mounting channel  
104 configured to form a mating connection with mounting  
channel 99 on top elements 96. Thus, rod 102 may be  
30       inserted through axial hole 100 on each top element 96 and  
through top hole 106 to form a substantially integral piece  
between top element 96 and internal lamina 90.

      End-and-stud laminae 88 are configured with a channel  
108 extending in the axial direction. When top element 96  
35       is placed on an end lamina, the mounting channel of the top  
element is left open. Thus, the head or nut on the rod 102

1 extending through the top elements lies within the mounting  
channel and does not protrude beyond the end of the liner  
segment.

5 Because end-and-stud laminae 88 do not include a top  
mounting hole, the top elements corresponding to each end-  
and-stud laminae are not directly attached to the end-and-  
stud laminae. The top elements are, however, tied to the  
end-and-stud laminae indirectly through the adjacent top  
10 elements which are directly attached to internal laminae  
90.

Although the present invention has primarily been  
described with reference for use with an ore grinding mill,  
it will be appreciated by one of ordinary skill in the art  
that the present invention may be used in a variety of  
15 applications. For example, Figure 6 illustrates the  
utilization of the present invention on a rock impact  
crusher. As with liners in ore grinding mills, blow bars  
on impact crushers are ideally constructed of a material  
having an optimum combination of hardness and toughness.

20 Blow bars are typically made in one-piece sections in  
order to facilitate removal and replacement. Also, blow  
bars can be manufactured more economically if they are cast  
as one section. Thus, as with liners for ore grinding  
mills, blow bar design has tended toward large one-piece  
25 sections. Because of the size of the sections, the ability  
to control the metallurgical properties of the blow bar by  
heat treating is restricted. However, by using the laminar  
design of the present invention, blow bars may be  
manufactured to have predetermined metallurgical  
30 characteristics obtained through heat treatment while  
providing a one-piece section for ease of installation.

Blow bars are attached to the rotor mechanically with  
bolts or in interlocking fit between the rotor and the blow  
bar. Approximately 50 percent of the weight of the blow  
35 bar is necessary to allow for attachment and this portion  
remains unworn throughout the effective life of the blow

1 bar. The present invention may be used to provide a  
separate wear tip which is mounted to a carrier bar to form  
the blow bar. Having replaceable wear tips allows that  
5 portion of the blow bar which remains unworn to be reused.  
When utilizing the present invention to provide a wear tip  
on the blow bar, the wear tip is subject to wear while  
preserving and protecting the carrier bar. This  
significantly reduces the scrap out weight associated with  
the blow bar.

10 As illustrated in Figure 6, a blow bar, generally  
designated at 110, includes a wear tip 111 attached to a  
carrier bar 112 according to the teachings of the present  
invention. The wear tip comprises a series of internal  
15 laminae 114 in combination with a series of end-and-stud  
laminae 116. A stud anchor 118 fits within the mounting  
channels 119 of the stud laminae 116.

Thus, two end-and-stud laminae are employed in mating  
connection wherever it is desired to locate a stud anchor.  
Additionally, an end-and-stud lamina is used at each end of  
20 the wear tip and oriented with mounting channel 119 facing  
outwardly such that the head of rod 122 and nut 123 which  
are used to attach together the laminae (as described  
below) rest within the mounting channel and do not protrude  
beyond the exterior face of the end laminae.

25 The laminae are attached together to form an integral  
wear tip by first stacking together laminae corresponding  
to the axial length of wear tip desired, where the axial  
direction is denoted by Arrow A. The laminae are then  
aligned by means of a mating tab 120 and recess 121  
30 configured on each laminae, as previously described in  
connection with the mill liner segments. A rod 122 is then  
placed through axial holes 124 in the laminae and axial  
holes 126 in the stud anchors and affixed at its end by a  
nut 123.

35 Wear tip 111 is mounted to carrier bar 112 with  
mounting bolts 128 which extend through mounting holes in

1 carrier bar 112 and are threaded into transverse holes 132  
in the stud anchors. It will be appreciated that mounting  
bolt 128 may include a threaded rod, a cap screw or any  
5 other apparatus known in the art for mounting such pieces  
together, whether by threaded connection or otherwise.

In operation, the wear tip may be quickly and easily  
mounted or removed from the carrier bar by means of  
mounting bolts 128. Use of the present invention permits  
superior metallurgical qualities to be obtained in the wear  
10 tip of the blow bar which heretofore have not been  
available in the one-piece blow bars of the prior art.

When manufacturing blow bars, it is desirable to  
maximize the tonnage of rock crushed with one blow bar.  
The life of the blow bar may be increased, and thereby  
15 increase the tonnage of crushed rock per blow bar, by  
increasing the life of the wear tip. In use, the wear tip  
becomes worn along the leading edge, denoted at 143,  
because it is leading edge 134 which has primary exposure  
to the rock being crushed against the apron (not shown).

20 To extend the life of the wear tip, the blow bar may  
be used until the leading edge of the wear tip becomes  
worn. The wear tip may then be removed from the carrier  
bar and rotated 180 degrees about the transverse direction  
(arrow C) and reattached to the carrier bar. Thus, edge  
25 136 becomes the leading edge and the effective life of the  
wear tip is approximately doubled.

From the foregoing, it will be appreciated that the  
present invention provides methods and apparatus for  
providing surfaces for use in high impact applications such  
30 as in ore comminution. For example, the present invention  
may be implemented to provide a liner for use in protecting  
the shell of an ore grinding mill which can be easily and  
inexpensively attached to and removed from the mill shell.  
The unique mounting apparatus employed by the present  
35 invention enable through holes to be eliminated from the  
liner segments and permits the liner segments to quickly be

1 mounted to the shell of the mill while avoiding the  
mounting problems which typically arise when through holes  
are eliminated.

5 The present invention also provides a liner design  
which may be cast and heat treated such that the  
microstructure of the liner may be controlled, thereby  
producing a liner having substantially the same  
microstructure throughout the liner. The laminar  
10 construction of the present invention minimizes the  
temperature gradients which occur upon cooling in other  
liner designs, which temperature gradients prevent certain  
microstructures from being achieved throughout the liner.  
The minimized temperature gradients also effectively reduce  
the risk that the laminae which comprise the liner segment  
15 will crack during the heat treating process. Thus, the  
liners of the present invention have substantially the same  
degree of hardness and toughness throughout the liner and  
the amount of hardness and toughness may be controlled  
during the manufacturing process.

20 The liners of the present invention may be mounted to  
the shell of the mill in such a way that through holes in  
the wear zone of the liner are eliminated, thereby  
eliminating the weak area which accompanies the existence  
of such holes. The two-piece liner bolt design used in  
25 mounting the liner segments of the present invention enable  
the through holes to be eliminated while not unduly  
complicating the mounting process because of their removal.

In addition to the use of the present invention in  
providing a liner for a mill shell, the present invention  
30 is also described for use as a wear tip on a blow bar for  
a rock impact crusher. The laminar assembly of the present  
invention permits a blow bar to be manufactured with  
superior metallurgical properties than heretofore available  
in blow bars while employing a mounting mechanism which  
35 enables the wear tip to be quickly and easily mounted or  
removed.

1       It will be appreciated that the apparatus and methods  
of the present invention are capable of being incorporated  
in the form of a variety of embodiments, only a few of  
which have been illustrated and described above. The  
5       invention may be embodied in other forms without departing  
from its spirit or essential characteristics. The  
described embodiments are to be considered in all respects  
only as illustrative and not restrictive, and the scope of  
the invention is, therefore, indicated by the appended  
10       claims rather than by the foregoing description. All  
changes which come within the meaning and range of  
equivalency of the claims are to be embraced within their  
scope.

What is claimed is:

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1 1. A laminar segment for use as an impact surface in  
comminution equipment, comprising:

5 a plurality of laminae configured such that the  
laminae may be associated together to form an integral  
segment, each lamina having a wear section with a face  
thereon, a core, and being configured such that the  
axial distance from the center of the core to the face  
of the wear section is less than the distance from the  
center of the core to any other surface of the wear  
10 section;

means for combining the plurality of laminae to  
form an integral segment; and

15 means for attaching the integral segment to the  
comminution equipment.

2. A liner segment for use as an impact surface in  
comminution equipment as defined in claim 1, wherein the  
means for combining the plurality of laminae includes means  
for applying compressive forces to the plurality of laminae  
20 to form an integral segment.

3. A liner segment for use as an impact surface in  
comminution equipment as defined in claim 1, wherein the  
means for combining the plurality of laminae comprises a  
25 high-strength rod which extends substantially the entire  
length of the integral segment in the axial direction.

4. A liner segment for use as an impact surface in  
comminution equipment as defined in claim 3, wherein the  
30 rod engages each of the laminae.

5. A liner segment for use as an impact surface in  
comminution equipment as defined in claim 3, wherein the  
means for attaching the integral segment to the comminution  
35 equipment comprises a plurality of attachment mechanisms  
which are attached to the rod.



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6. A liner segment for use as an impact surface in comminution equipment as defined in claim 5, wherein the comminution equipment is an ore grinding mill having a shell and the attachment mechanisms are configured to extend from the rod through the shell of the mill.

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7. A liner segment for use as an impact surface in comminution equipment as defined in claim 6, wherein the comminution equipment is a rock impact crusher having a carrier bar and the attachment mechanisms are configured to extend from the rod through the carrier bar such that the laminar segment may be mounted to the carrier bar.

15

8. A liner segment for use as an impact surface in comminution equipment as defined in claim 1, wherein the surface of each lamina includes a front face and a back face and the laminae are associated together such that the front faces of adjacent laminae are directed towards each other and the back faces of adjacent laminae are directed towards each other.

20

9. A liner segment for use as an impact surface in comminution equipment as defined in claim 8, wherein the front face and the back face of the laminae are perpendicular to a line in the axial direction.

25

10. A liner segment for use as an impact surface in comminution equipment as defined in claim 1, further comprising means for preventing relative movement of the laminae.

30

11. A liner segment for use as an impact surface in comminution equipment as defined in claim 10, wherein the means for preventing relative movement of the laminae includes a recess configured in one lamina and a

35

1 corresponding tab configured in an adjacent lamina such  
that the recess and the tab engage when the laminae are  
combined to form the integral segment.

5 12. A liner segment for use as an impact surface in  
comminution equipment as defined in claim 1, wherein the  
plurality of laminae comprise a first plurality of laminae  
and further comprising a second plurality of laminae and  
means for attaching the first plurality of laminae to the  
10 second plurality of laminae.

13. A liner segment for use as an impact surface in  
comminution equipment as defined in claim 12, wherein the  
means for attaching the first plurality of laminae to the  
15 second plurality of laminae comprises a first high-strength  
rod which extends substantially the entire length of the  
integral segment in the axial direction.

14. A liner segment for use as an impact surface in  
20 comminution equipment as defined in claim 13, wherein the  
means for attaching the integral segment to the comminution  
equipment comprises a second high-strength rod which  
extends substantially the entire length of the integral  
segment in the axial direction, the second rod having a  
25 head and a nut.

15. A liner segment for use as an impact surface in  
comminution equipment as defined in claim 14, wherein the  
means for attaching the integral segment to the comminution  
30 equipment further comprises a plurality of mounting bolts  
and a stud anchor corresponding to each mounting bolt, each  
stud anchor having an axial hole which engages the second  
high-strength rod and being configured for engagement with  
the corresponding mounting bolt.  
35

1 16. A liner segment for use as an impact surface in  
comminution equipment as defined in claim 15, wherein the  
second plurality of laminae includes internal laminae  
5 configured with an axial hole for engagement with the first  
high-strength rod and end-and-stud laminae configured with  
a mounting channel.

10 17. A liner segment for use as an impact surface in  
comminution equipment as defined in claim 16, wherein the  
mounting channel is configured such that a pocket for  
receiving a stud anchor may be formed when two internal  
laminae are placed in adjacent connection.

15 18. A liner segment for use as an impact surface in  
comminution equipment as defined in claim 17, wherein the  
laminar segment has two ends and an end-and-stud lamina is  
employed at each end and oriented such that the head and  
nut on the second rod rest within the mounting channels of  
the end-and-stud laminae.

20 19. A laminar assembly for use as an impact surface in  
comminution equipment, comprising:

25 a plurality of integral metal laminae having a  
core and a surface, each of which has been heat  
treated for hardness, each lamina being dimensioned  
such that upon heat treating the core microstructure  
is substantially equivalent to the surface  
microstructure; and

30 means for attaching the integral laminae to the  
comminution equipment.

35 20. A laminar assembly for use as an impact surface in  
comminution equipment as defined in claim 19, wherein the  
microstructure is a martensitic microstructure.

1 21. A laminar assembly for use as an impact surface in  
comminution equipment as defined in claim 20, wherein the  
laminae are made of iron having a carbon content greater  
5 than approximately 1.25 percent.

22. A laminar assembly for use as an impact surface in  
comminution equipment as defined in claim 21, wherein the  
iron is a high-chromium, white iron.

10 23. A laminar assembly for use as an impact surface in  
comminution equipment as defined in claim 20, wherein the  
laminae are made of a steel having a carbon content between  
about 0.3 percent and about 0.7 percent.

15 24. Individually sized segments for attachment to a  
mounting surface of comminution equipment, comprising:

a plurality of laminae configured to mate into an  
integral laminar assembly prior to attachment to the  
comminution equipment;

20 a connector engaging each of a predetermined  
number of essentially identical laminae such that the  
laminar assembly is secured integrally together by the  
connector in any one of a plurality of axial lengths;  
and

25 means for attaching the integral laminar assembly  
to the mounting surface of the comminution equipment.

25. Individually sized segments for attachment to a  
mounting surface of comminution equipment as defined in  
30 claim 24, wherein the connector is configured to engage the  
laminae such that the laminae are placed in compression.

26. Individually sized segments for attachment to a  
mounting surface of comminution equipment as defined in  
35 claim 24, wherein the connector comprises a high-strength  
rod and wherein each lamina includes a base and a wear

1 section and the base is configured with a hole extending in  
an axial direction through which the rod is connected to  
the laminae.

5 27. Individually sized segments for attachment to a  
mounting surface of comminution equipment as defined in  
claim 26, wherein the means for attaching the integral  
laminar assembly to the mounting surface of the comminution  
10 equipment includes a plurality of attachment mechanisms in  
connection with the rod.

28. Individually sized segments for attachment to a  
mounting surface of comminution equipment as defined in  
claim 27, wherein each attachment mechanism includes a  
15 head, the head being configured with a hole extending  
therethrough through which the rod is connected to the  
attachment mechanisms.

20 29. Individually sized segments for attachment to a  
mounting surface of comminution equipment as defined in  
claim 28, wherein the laminae are configured such that a  
pocket is configured in the base of adjacent laminae for  
receiving the head of the attachment mechanism.

25 30. An attachment mechanism for mounting a laminar segment  
to a mounting surface of a piece of comminution equipment,  
comprising:

30 a laminar segment; and  
a plurality of two-piece bolts attached to the  
laminar segment, each two-piece bolt comprising:  
a first end attached to the laminar segment,  
a second end, and  
means for attaching the first end to the  
second end.

35

- 1 31. An attachment mechanism for mounting a laminar segment  
to a mounting surface of a piece of comminution equipment  
as defined in claim 30, the attachment mechanism further  
5 comprising a conventional bolt used in the attachment of a  
liner to the shell of an ore grinding mill, the bolt being  
attached to the laminar segment.
- 10 32. An attachment mechanism for mounting a laminar segment  
to a mounting surface of a piece of comminution equipment  
as defined in claim 30, wherein the means for attaching the  
first end to the second end comprises a male member which  
may threadably engage a female member.
- 15 33. An attachment mechanism for mounting a laminar segment  
to a mounting surface of a piece of comminution equipment  
as defined in claim 32, wherein the male member is  
configured on the first end and the female member is  
configured on the second end.
- 20 34. An attachment mechanism for mounting a laminar segment  
to a mounting surface of a piece of comminution equipment  
as defined in claim 33, wherein each bolt includes a head  
which is configured with a hole therethrough through which  
a rod may be placed such that the bolts may be attached to  
25 the laminar segment.
- 30 35. An attachment mechanism for mounting a laminar segment  
to a mounting surface of a piece of comminution equipment  
as defined in claim 30, wherein the laminar segment  
includes a plurality of laminae with a pocket formed  
between selected adjacent laminae and the first end of the  
attachment mechanism comprises a stud anchor which is  
configured to fit within the pocket.
- 35 36. An attachment mechanism for mounting a laminar segment  
to a mounting surface of a piece of comminution equipment

1 as defined in claim 35, wherein the stud anchor is  
configured such that it does not protrude from the laminar  
segment.

5 37. An attachment mechanism for mounting a laminar segment  
to a mounting surface of a piece of comminution equipment  
as defined in claim 35, wherein the stud anchor is  
configured with an axial hole extending therethrough  
10 through which a rod may be placed such that the stud anchor  
may be attached to the laminar segment.

38. An attachment mechanism for mounting a laminar segment  
to a mounting surface of a piece of comminution equipment  
as defined in claim 35, wherein the second end of the bolt  
15 is configured to extend from the stud anchor through the  
mounting surface of the comminution equipment.

39. An attachment mechanism for mounting a laminar segment  
to a mounting surface of a piece of comminution equipment  
20 as defined in claim 38, wherein the second end of the bolt  
comprises a threaded rod.

40. An attachment mechanism for mounting a laminar segment  
to a mounting surface of a piece of comminution equipment  
25 as defined in claim 38, wherein the second end of the bolt  
comprises a cap screw.

41. An attachment mechanism for mounting a laminar segment  
to a mounting surface of a piece of comminution equipment  
30 as defined in claim 35, wherein the means for attaching the  
first end to the second end comprises a threaded female  
member on the first end and a threaded male member on the  
second end, the threaded female and male member configured  
to threadably engage each other.

35

1 42. A method for lining a mill shell, comprising the steps  
of:

5 forming a plurality of metal laminae in a  
predetermined configuration having an axial dimension  
less than the radial dimension;

heat treating the metal laminae such that the  
microstructure of each lamina is substantially  
equivalent throughout the lamina;

10 attaching the lamina together to form an integral  
liner segment assembly; and

mounting the liner segment assembly to a mill  
shell.

15 43. A method for lining a mill shell as defined in claim  
42, wherein the mounting step includes attaching at least  
two liner bolts to each liner segment assembly.

20 44. A method for lining a mill shell as defined in claim  
42, wherein the forming step includes configuring each  
laminae with a wear section and a base with a hole through  
the base and the attaching step includes inserting a rod  
through the hold in the base of each lamina and threading  
and tightening a nut on the end of the rod such that the  
laminae are firmly mounted to each other.

25 45. A method for lining a mill shell as defined in claim  
44, wherein the threading step is preceded by heating the  
rod such that the length of the rod expands and the  
tightening step is completed before the rod contracts to  
30 its original length.



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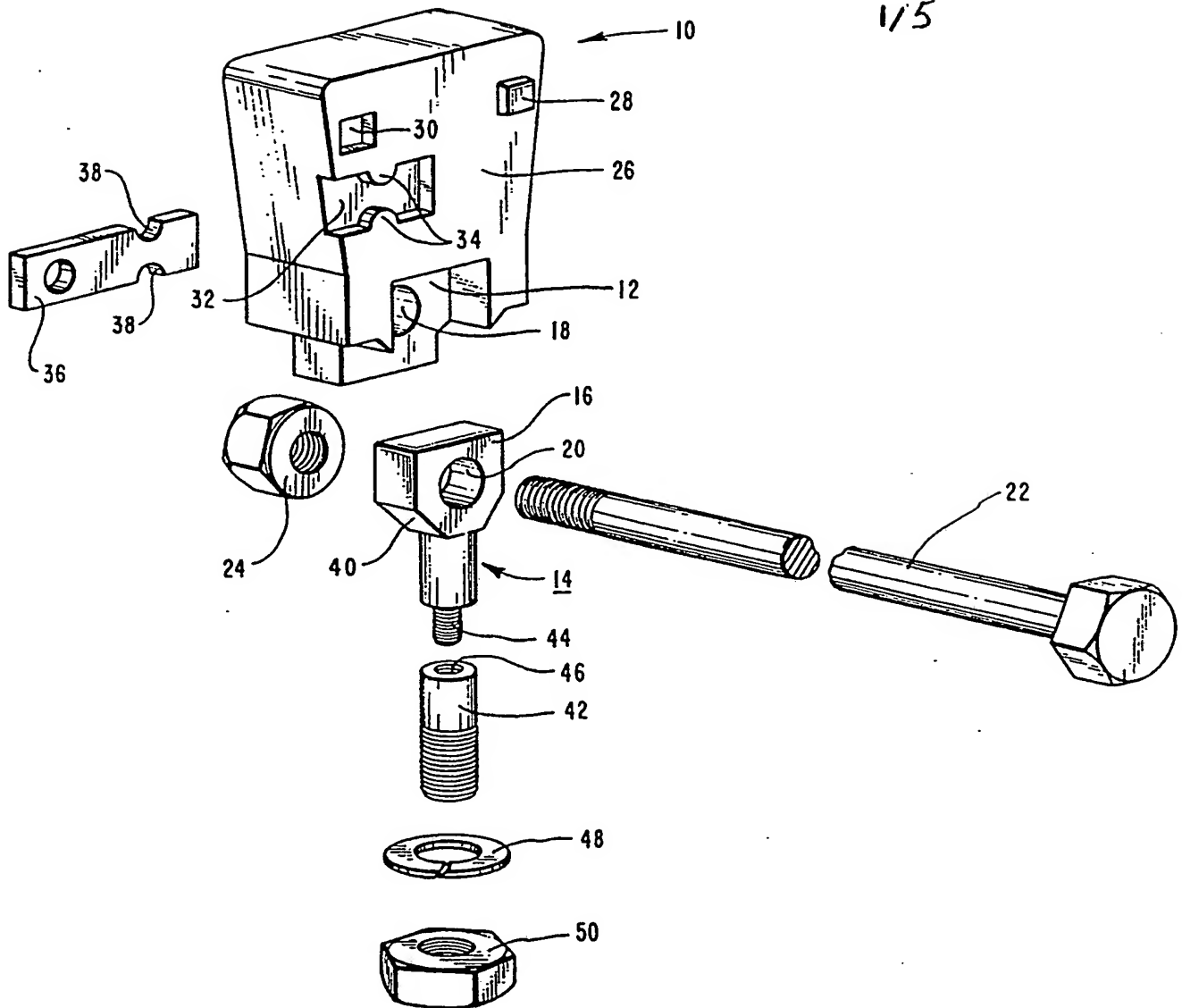


FIG. 1

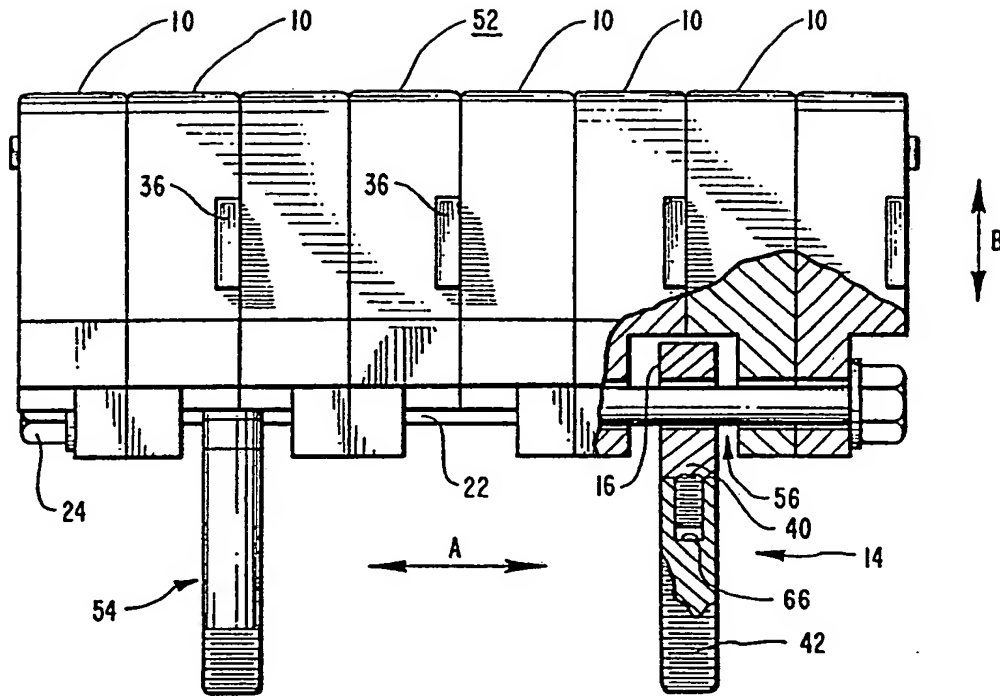


FIG. 2

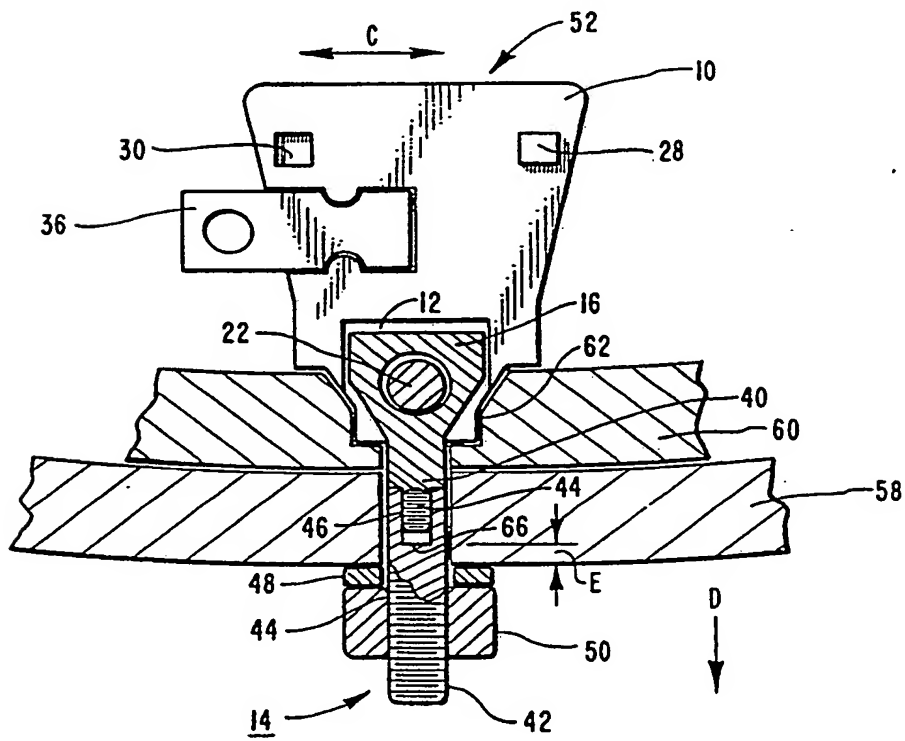


FIG. 3

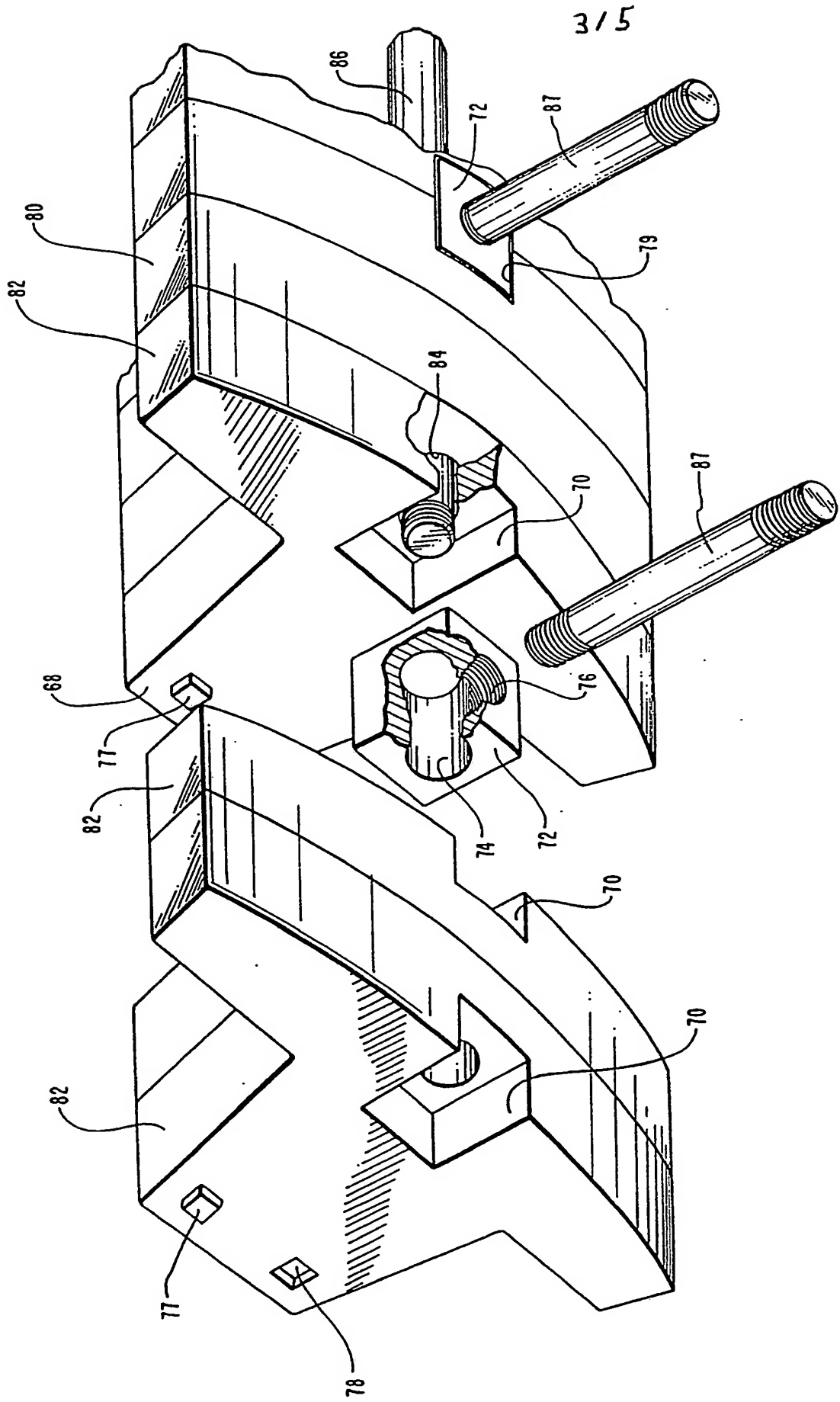


FIG. 4

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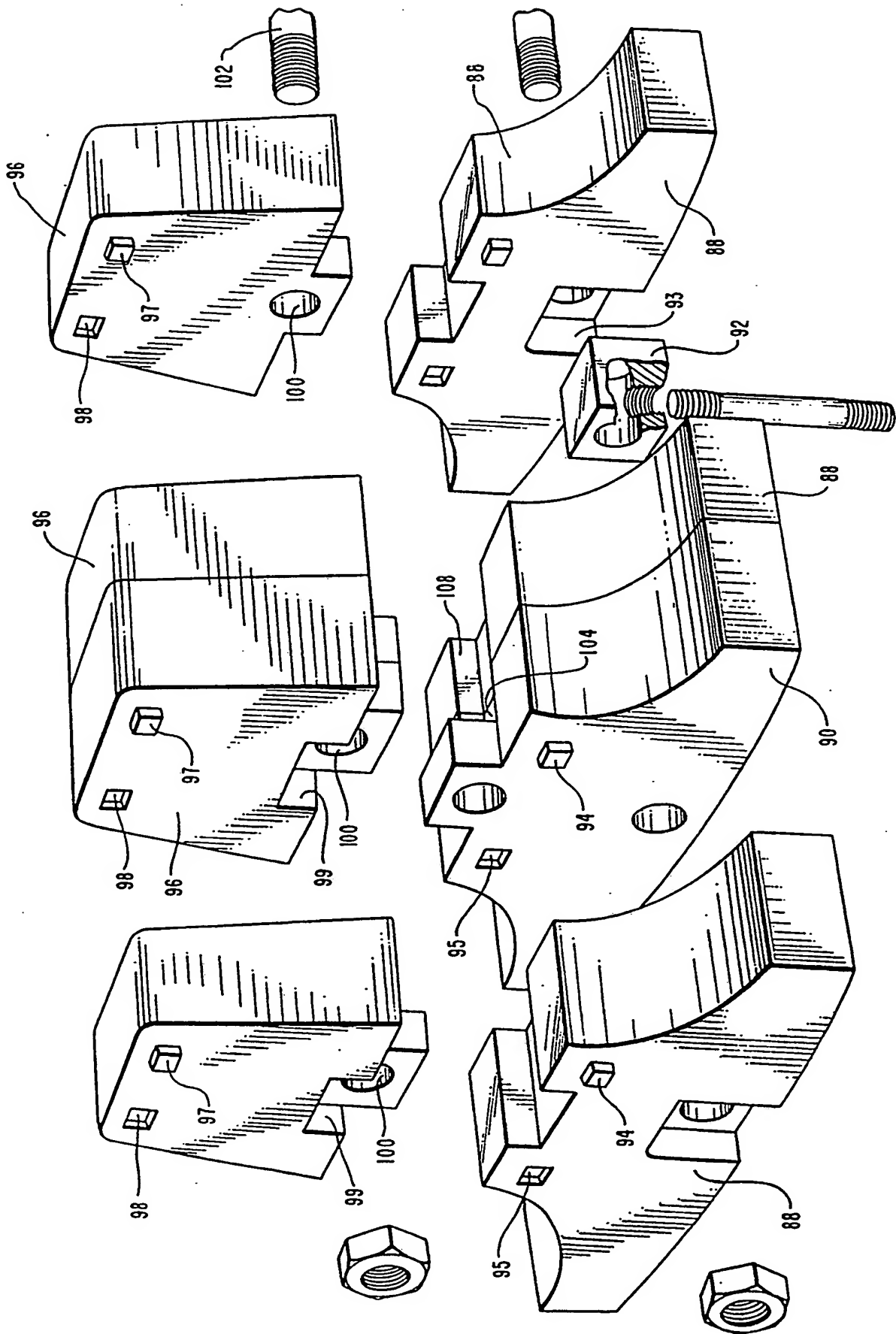


FIG. 5



# INTERNATIONAL SEARCH REPORT

International Application No. PCT/US90/00146

## I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) <sup>6</sup>

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5) B02C 13/28

US 241/182

## II. FIELDS SEARCHED

Minimum Documentation Searched <sup>7</sup>

Classification System

Classification Symbols

US

29/525.1, 576.2

241/181, 182, 183, 264-269, 275, 299, 300

Documentation Searched other than Minimum Documentation  
to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>

## III. DOCUMENTS CONSIDERED TO BE RELEVANT <sup>9</sup>

Category <sup>*</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
A	US, A, 1,309,807 (NEWHOUSE) 15 JULY 1919. See entire document.	1-42
X	US, A, 2,275,992 (RAHNER) 10 MARCH 1942. See entire document.	1, 2, 8-10, 24, 25
A	US, A, 2,465,607 (ROUBAL) 29 MARCH 1949. See entire document.	1-42
A	US, A, 3,353,758 (WHALEY ET AL.) 21 NOVEMBER 1967. See entire document.	1-42
X	US, A, 3,844,492 (SMALLWOOD ET AL.) 29 OCTOBER 1974. See entire document.	30, 31-34
X	US, A, 3,893,634 (SCHMIDT) 08 JULY 1975. See entire document.	30, 32, 33
X	US, A, 4,181,266 (GEORGET ET AL.) 01 JANUARY 1980. See entire document.	30, 32, 33
A	US, A, 4,559,986 (SVENSSON ET AL.) 24 DECEMBER 1985. See entire document.	1-42

<sup>\*</sup> Special categories of cited documents: <sup>10</sup>

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"Δ" document member of the same patent family

## IV. CERTIFICATION

Date of the Actual Completion of the International Search

20 MARCH 1990

International Searching Authority

ISA/US

Date of Mailing of this International Search Report

03 MAY 1990

Signature of Authorized Officer:

*Timothy V. Eley*  
TIMOTHY V. ELEY